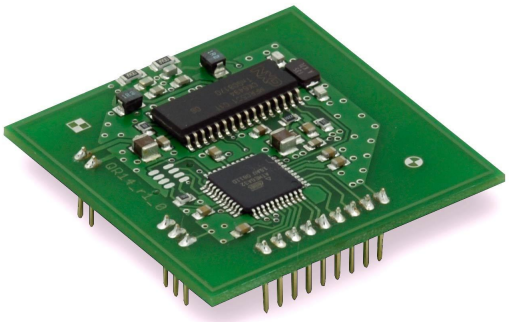
MiFare Protocol Guide

for metraTec MiFare Readers and Modules



Date: June 2009

Version: 1.0

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List of Abbreviations

ATQA	Answer to request, ISO 14443A – a number code showing some information on the card. See Appendix for examples.
PICC	Proximity IC Card (the official word for transponder card)
SAK	„Select Acknowledge“ – a number code showing some information on the card, e.g. type of card, etc. See Appendix for examples.
UID	Unique ID (of every ISO14443 Transponder)

1. Introduction

This document describes the metraTec firmware protocol for all metraTec RFID readers that work with RFID transponders according to ISO14443A/MiFare (by NXP). This includes the DeskID MiFare USB, the QR14 OEM module as well as several custom reader units.
The target audience for this document are programmers, who need to communicate with the reader and want to write their own software for this task. This software can be written in any programming language, such as C#, Java, Delphi, Ansi-C, and even directly in IEC 61-131 Code, e.g. with CodeSys.

The reader firmware offers an ASCII based programming interface. The instructions are identified by an easy to remember, three character string usually followed by mandatory parameters and/or optional parameters. The response format depends on the type and result of an instruction.

This manual starts with all commands that the reader supports. These instructions are divided into several main groups:

- Reader Instructions
- Tag Manipulation Instructions, divided into:
    - General ISO14443A instructions
    - MiFare Classic specific commands

All Instructions have Error-Codes which are described in the Appendix. The Appendix also includes further information on the memory structure and security model of MiFare transponders, including access rights and access key – a topic that can be quite complex. If you haven't worked with ISO14443A or MiFare transponders before, you should read this first.

1.1. General Procedure

The general process for reading or writing data to or from a MiFare transponder is alwas the same and consists of the following steps. While there might be several ways to complete the same task including more complex ones, the following list shows the easiest and quickest way:

1. Save the right key to use in the reader crypto unit, using the STK command. This is only necessary if the correct key has not been permanently stored in the reader using the SSK command before.
2. Tell the reader which key to use (Temp Key or one of the up to 24 permanent keys) using the SKU command.
3. Use an inventory command (INV) to find all cards in the field. The result will give you the UIDs of all the transponders in the field.
4. Select the card you want to use with the SEL command – either manually by using the UID you got in the step before or by using the automatic mode.
5. After activating the card with the select command you have to authenticate the block you want to read/write data to/from using the AUT command.
6. If that was successful, you can start reading and writing data to the memory of the transponder using the RDT (read date) or write data (WDT) command.

1.2. Further Documents

For an even deeper understanding of the operating principle it might be useful to read all datasheets and norms regarding your transponder IC, esp. ISO 14443-3.

2. Communication Principle

The communication between the reader and the host system is based on ASCII strings. Each string is terminated with a carriage-return and will be transmitted with MSB fist.

The communication from the reader to the host system (i.e. the response) is the same as above but in most cases the response from the reader comprises more than one line.

General line:

```
Instruction<SPACE>Parameter<Space>Parameter<CR>
```

Example without Parameter:

```
REV<CR>
```

in ANSI C:

char Rev[4] = {'R','E','V',13};

The first values which will be sent is 'R' (52h), followed by 45h, 56h, 0dh. Some instructions may be specified with parameters, which are separated by a space (20h).

Example with Parameter

```
INV<SPACE>SSL<CR>
```

char Inv[8] = {'I','N','V',0x20,'S', 'S', 'L' ,0x0D};

3. Reader Instructions

This list gives an overview of all the existing instructions that directly influence the reader itself. All commands that are connected to the transponder, can be found in the next chapter.

Command	Name	Description
RST	Reset	Resets the Reader
REV	Revision	Returns hardware and software version
STB	Standby	Sends the reader into standby/sleep mode for power saving
WAK	Wake Up	Ends standby/sleep mode
RIP	Read Input Pin	Reads the state of an input pin
WOP	Write Output Pin	Writes the state of an output pin
CON	CRC on	Turns on CRC checking of computer / reader communication
COF	CRC off	Turns off CRC checking of computer / reader communication
SSK	Set Static Key	Saves up to 24 keys in the EEPROM of the reader
STK	Set Temporary Key	Save one key in the readers master key buffer
SKU	Set Key to Use	Sets which key should be used to authenticate a tag

Table **1**: *Overview of reader manpulation instructions*

3.1. Reset (RST)

The reset command resets the reader. The Reset command has no parameters. After sending the RST command the HF power is turned off and the reader has to be initialized again.

Instruction:

```
RST<CR>
```

Response, if successful:

```
OK!<CR>
```

Possible Error Response:

```
UPA<CR>
```

3.2. Revision (REV)

The revision command requests the device type and hard- and software revision of the reader. The reader returns its device type and it's hard- and software revision. Revision has no parameters and returns no error codes.

Instruction:

```
REV<CR>
```

Response, if successful:

```
PRODUCT_NAME<SPACE>HW_revision[4bytes]SW_revision[4bytes]<CR>
```

15 Bytes product name (filled with Spaces) + 4 bytes HW-Revision + 4 Bytes Software-Revision + <CR>

Possible Error Response:

```
UPA<CR>
```

Example for a response:

```
DESKID_ISO<5 Times Space>01000101<CR>
```

Interpretation: Product name: DESKID_ISO

Hardware-Revision: 01.00

Software-Revision: 01.01

3.3. Standby (STB)

The standby command sets the reader in a power save mode. The RF power is turned off. This means that all tags that might be in the field will also be powered down. If successful it returns GN8 ("Good Night"). The reader will not accept any commands until a Wake Up Command (WAK) is received. Standby has no parameters.

Instruction:

```
STB<CR>
```

Response, if successful:

```
GN8<CR>
```

Possible Error Response:

```
UPA<CR>
```

3.4. Wake Up (WAK)

The wake up command ends the power save mode. Reader will restore its last state prior to the standby. If successful it returns GMO (“Good Morning”). Wake up has no parameters.

Instruction:

```
WAK<CR>
```

Response, if successful:

```
GMO<CR>, DNS<CR> (if not in Standby-Mode)
```

Possible Error Response:

```
UPA<CR>
```

3.5. Read Input Pin (RIP)

This command is used to read the current state of an input pin. It takes one parameter, which is the two-digit, hex-coded, zero-based number of the input pin to be read. The possible parameter range is 00 to 01.

If successful, it returns either HI! or LOW depending on whether the input pin is high or low.

Instruction:

```
RIP<SPACE>Pin_No<CR>
```

e.g. (to read the first input pin): RIP 00<CR>

Response, if successful:

`HI!<CR>` for High-State

`LOW<CR>` for Low-State

Possible Error Response:

```
NOR<CR>, EHX<CR>, UPA<CR>
```

3.6. Write Output Pin (WOP)

This command is used to set the state of an output pin either to high or to low. It takes two parameters. The first parameter is the two-digit, hex-coded, zero-based number of the output pin to be written to. The second parameter is either “HI” or “LOW” to set the according pin to high or low respectively. The possible parameter range is 00 to 03.

Instruction:

```
WOP<SPACE>Pin_No<SPACE>PIN_Setting<CR>
```

e.g. Set pin 0 high: `WOP<SPACE>00<SPACE>HI<CR>`

e.g. Set pin 0 low: `WOP<SPACE>00<SPACE>LOW<CR>`

Response, if successful:

`OK!<CR>`

Possible Error Response:

`NOR<CR>, EHX<CR>, UPA<CR>`

3.7. Cyclic Redundancy Check On (CON)

This commands turns on the Cyclic Redundancy Check (CRC) of the computer-to-reader communication. This is used to detect transmission errors between the reader and the computer. In general this feature is not necessary except in scenarios where you have lots of noise on the communication bus (e.g. when using USB communication in the vicinity of electric motors) or you encounter any other problems with communication errors.

If this feature is activated (default is off), the reader firmware expects a CRC16 (4 hex numbers) between all commands to the reader and the respective <CR>. Between the command and the CRC there is a space character which is included in the CRC calculation. All answers from the reader will also be extended accordingly. The CRC used uses the 8408 polynomial, starting value is 0xFFFF. This command will work with or without the (optional) CRC.

If successful the command returns OK! plus the according CRC of "OK! ".

Appendix 1 shows a function in C, C# & Java to calculate the correct CRC16.

Instruction:

`CON<CR>`

or:

`CON 819E<CR>, con 2EC5<CR>`

Response, if successful:

`OK! 9356<CR>`

Possible Error Response:

`UPA<CR>`

3.8. Cyclic Redundancy Check Off (COF)

This command turns off the Cyclic Redundancy Check (CRC) of the computer-to-reader communication. This is the default setting. This command will work with or without the (optional) CRC.

If successful it returns OK!.

Instruction:

```
COF<CR>, or COF 4F5E<CR>, or cof E005<CR>
```

Response, if successful:

```
OK!<CR>
```

Possible Error Response:

```
UPA<CR>
```

3.9. Save Static Key (SSK)

The reader has a persistent memory which is able to save up to 24 keys for the MiFare Crypto1 unit. The static keys in the memory of the chip are not readable and are directly used by the Crypto1 unit of the reader. They will not be transmitted over the air interface.

Note: The sector no. is zero based

Instruction:

```
SSK<SPACE>[Loc]<SPACE>[Key]<CR>
```

Parameter	Description
Loc	Location where the key will be saved (0<=Loc<=23)
Key	6 Bytes ASCII-String (12 chars), LSB first

*Table **2**: Save Static Key parameter description*

Response, if successful:

```
OK!<CR>
```

Examples:

Save the key 112233445566h in sector 0

```
SSK<SPACE>0<SPACE>112233445566<CR>
```

Save the key FFFFFFFFFFFFh in sector 23

```
SSK<SPACE>23<SPACE>FFFFFFFFFFFF<CR>
```

Possible Error Response:

`UPA<CR>`	Unknown parameter
`EDX<CR>`	Location fail, or other characters than 0-9
`EHX<CR>`	Key-Parameter is missing or other characters than 0-9 and A-F
`WDL<CR>`	Key is not 6 bytes long
`NOR<CR>`	Location given is higher than 23

3.10. Save Temporary Key (STK)

This command saves one key in the reader temporarily until a power down or a reset occurs. The only parameter is the Key to save, which is a 6 Byte ASCII String (12 Chars).

Instruction:

```
STK<SPACE>[Key]<CR>
```

Response, if successful:

```
OK!<CR>
```

Examples:

Save the key 112233445566h

```
STK<SPACE>112233445566<CR>
```

Possible error codes:

`UPA<CR>`	Unknown parameter
`EHX<CR>`	Key-Parameter is missing or other characters than 0-9 and A-F
`WDL<CR>`	Key is not 6 bytes long

3.11. Set Key to Use (SKU)

The key which will be used to authenticate a MiFare chip resp. a block of a MiFare Chip, has to be selected with this command before using the standard authentification command (AUT). If the direct mode from the authentication command is used, this command is not necessary. The key can either be the temporary key or the static key.

Instruction:

SKU<SPACE>{Type}<SPACE>[Loc]<CR>

Parameter	Description
Type	The type of the key: TEMP chooses the temporary key STAT chooses the static key
Loc	Use this parameter only with STAT-Parameter! Specifies the zero based location of the static key. See SSK command.

*Table **3**: Set Key to Use parameter description*

Response, if successful:

OK!<CR>

Examples:

Use the temporary key

SKU<SPACE>TEMP<CR>

Use the static key in location 2

SKU<SPACE>STAT<SPACE>2<CR>

Possible error codes:

UPA<CR> Unknown parameter

EDX<CR> Location fail, or other characters than 0-9 given

NOR<CR> Location given is higher than 23

KNS<CR> Key Not Set (if temporary key is selected, but not set before)

4. General ISO 14443A Commands

This list gives an overview of the existing commands that can be used with any transponder that is based on ISO14443A, including all MiFare dialects. Any commands that are specific to a certain type of MiFare-Type can be found in the next chapter.

Command	Name	Description
INV	Inventory	Returns all UIDs from tags in read range
SEL	Select tag	Selects a tag
RDT	Read data	Get data from tag
WDT	Write data	Write Data to a tag

*Table **4**: Overview of general ISO 14443A commands*

4.1. Inventory (INV)

This command returns all UIDs from ISO/IEC 14443-1 to 3 compatible transponder, which are in the read range of the reader. Only single and double UIDs are supported (all types of ISO14443A known today). The length of the response can either be 4 bytes (single) or 7 bytes (double). Triple UIDs will be supported as soon as there are tags with this kind of UID.

Instruction:

```
INV<CR>
```

Response, if successful:

The UIDs, separated by a carriage return:

```
UID1<CR>
UID2<CR>
```

...

The end is marked by the line:

```
IVF<SPACE>[Count]
```
(Count is the number of transponders found)

Example:

```
INV<CR>
```

Response:

```
C22E5732<CR>
328DA79C<CR>
```

```
IVF 02<CR>
```

Possible error codes:

`UPA<CR>`	Unknown parameter

4.2. Select Tag (SEL)

Before you can exchange data with a MiFare chip, the transponder has to be activated (or „selected" in the ISO14443 language). There are two different modes to select a card. Manual Transponder Select (MTS), which needs the UID of the transponder (via a previous INV command) or Automatic Transponder Select (ATS).

4.2.1. Manual Transponder Select (MTS)

Use this mode to select a card where the UID is known (usually by doing an INV before). Only transponders with single or double UIDs are supported.

Instruction:

```
SEL<SPACE>MTS<SPACE>[UID]<CR>
```

Response, if successful:

`[SAK]<CR>`	see Appendix for the SAK codes of different chip versions

Examples:

Select a MiFare 1k Card (single UID)

```
SEL<SPACE>MTS<SPACE> AC410094<CR>
```

Select a MiFare Ultralight Card (double UID)

```
SEL<SPACE>MTS<SPACE> 047F77D18A0280<CR>
```

Possible error codes:

`UPA<CR>`	Unknown parameter
`TNR<CR>`	Tag not responding
`EHX<CR>`	The string cannot be interpreted as a valid UID or includes non hex characters

4.2.2. Automatic Transponder Select (ATS)

In this mode the reader will automatically select one card in the the read range randomly. This makes sense if you are sure that there is only one card in the field (e.g. because the reader is integrated into a card slot).

Sometimes it is useful to work with all cards in the field. For this purpose an optional parameter "CYC" exists. When using the "CYC" parameter it is necessary to run an inventory (INV) before. After that, all transponders in the inventory list will be selected cyclically by sending SEL ATS CYC for each transponder.

Instruction:

```
SEL<SPACE>ATS<SPACE>CYC<CR>
```

Response, if successful:

`[ATQA]<CR>`	see Appendix for the ATQA codes of different chip versions
`[SAK]<CR>`	see Appendix for the SAK codes of different chip versions
`[UID]<CR>`	

Examples:

Select a transponder currently in read range

```
SEL<SPACE>ATS<CR>
```

Select two transponders cyclically

```
INV<CR>
```

runs inventory round, e.g. with two transponders/UIDs in the field:

UID 1.: AC410094

UID 2.: C2DF6084

The select the first transponder (UID AC410094):

```
SEL<SPACE>ATS<SPACE>CYK<CR
```

Response:

```
0400<CR>
```

```
08<CR>
```

```
AC410094<CR>
```

The select the second transponder (UID C2DF6084):

```
SEL<SPACE>ATS<SPACE>CYK<CR
```

Response:

```
0400<CR>
```

```
08<CR>
```

C2DF6084<CR>

Possible error codes:

UPA<CR>	Unknown parameter
TNR<CR>	Tag not responding (left the field since the INV command)

4.3. Read Data from Tag (RDT)

The read data command is used to retrieve the data stored in a transponder. Normally it returns 16 bytes. For compatibility to other ISO/IEC 14443-1 to 4 transponder than MiFare classic, it has a direct read mode, marked with the first parameter "DRT". In this mode the second parameter is the custom command.

Additionally, this command supports the ability to read multiple blocks with one command, i.e. parameter "ALL" for all blocks of a sector, or "CNT" for a variable block count.

If MiFare classic is used, block has to be authenticated first (see the AUT command in the next chapter). The command returns all blocks from a sector. If MiFare 4K is used, parameter "All" is set and the authenticated block no. is higher than 127 it returns 16 blocks. For Custom-Read-Commands the length of a response is maximal 64 bytes.

Instruction:

Read single Block:

RDT<SPACE>[Block No.]<CR>

Read all blocks:

RDT<SPACE>ALL<CR>

Read variable number of blocks from block No.:

RDT<SPACE>CNT<SPACE>[Block No.]< SPACE>[No. of Blocks]<CR>

Direct Read:

RDT<SPACE>DRT<SPACE>[CMD] <SPACE>[Block No.]<CR>

Parameter	Description
Block No.	Read-Start-Block, respectively Block to read (absolute), one decimal byte
No. of Blocks	Number of blocks to read beginning at Block No., one decimal byte Has to be bigger then 0
ALL	Read-all-parameter, marked that all blocks from sector should be read, only MiFare 1k and 4k
CNT	Read-Count-parameter, marked that a variable number of blocks beginning at Block No. should be read
DRT	Direct-Read-Parameter, if a Transponder needs another command than 30h

CMD	Custom Read Command, one hexadecimal byte

*Table **5**: Read command parameter description*

Response, if successful:

Number of lines is equal to the number of read blocks. If "DRT" is not set each line is 16 Bytes (32 ASCII chars, hexadecimal) long.

i.e. for one read block:

```
00112233445566778899AABBCCDDEEFF<CR>
```

Examples:

Read all Blocks from sector

```
RDT<SPACE>ALL<CR>
```

Read block number 11d

```
RDT<SPACE>11<CR>
```

Read 2 Blocks beginning at block 0

```
RDT<SPACE>CNT<SPACE>0<SPACE>2<CR>
```

Read 14 Blocks beginning at block 129<CR>

```
RDT<SPACE>CNT<SPACE>129<SPACE>14<CR>
```

Possible error codes:

`UPA<CR>`	Unknown parameter
`EDX<CR>`	A decimal parameter includes non decimal characters
`BAE<CR>`	Block no. not readable, i.e. wrong key, see Block– and Access Mode
`BNA<CR>`	Block no. not authenticated (only MiFare classic)
`NMA<CR>`	No MiFare chip 1k or 4k authenticated (only ALL-Mode)
`NB0<CR>`	Number of blocks to Read is 0

4.4. Write Data to Tag (WDT)

The write data command normally stores 16 bytes of data into a block (data or trailer block). For compatibility to other ISO/IEC 14443-1 to 4 transponder than MiFare classic, the

command also has a direct write mode, marked with the first parameter “DRT”. The number of bytes will not be checked in this mode and it depends on the second parameter (Data).

To write to MiFare Ultralight cards (which only have four bytes per block) the first parameter becomes “W4”. This parameter writes 4 bytes to the card.

The selected block has to be writable for this command to work.

ATTENTION

If you write wrong data to the trailer block of a sector (the fourth block of every sector, e.g. block 3, 7, 11, etc.), the sector may become locked forever or be even unreadable afterwards. We recommend to use the STM command to change the information in the trailer blocks and don't write data to it directly (although it is possible).

Instructions:

Write 16 Bytes:

```
WDT<SPACE>[Data]<SPACE>[Block No.]<CR>
```

Write 4 Bytes:

```
WDT<SPACE>W4<SPACE>[Data]<SPACE>[Block No.]<CR>
```

Write directly:

```
WDT<SPACE>DRT<SPACE>[CMD]<SPACE>[Data]<SPACE>[Block No.]<CR>
```

Parameter	Description
Data	Hexadecimal ASCII-String which represents the data. The length depends on whether “DRT” or “W4” is set. If W4 is set the length is 8 ASCII characters (4 bytes). If nothing is set, then it is 32 ASCII characters (16 bytes).
W4	Write 4 bytes (for MiFare Ultralight)
DRT	If set: the direct mode will be used
CMD	Only with “DRT”, transponder specific write command (see datasheet)
Block No.	Absolute zero based block no. which should be written

*Table **6**:Write command parameter description*

Response, if successful:

```
OK!<CR>
```

Examples:

Write 16 bytes to block 18d

WDT<SPACE>00112233445566778899AABBCCDDEEFF<SPACE>18<CR>

Possible error codes:

UPA<CR>	Unknown parameter
EHX<CR>	The string cannot be interpreted as valid data or contains non hex characters
BAE<CR>	Block no. not readable, i.e. wrong key, see Block– and Access Mode
BNA<CR>	Block no. not authenticated (only MiFare classic)
NMA<CR>	No MiFare chip 1k or 4k authenticated (only ALL-Mode)
WDL<CR>	The hex string does not have the correct length (i.e. 16 bytes in normal mode)

5. MiFare Classic Commands

This section describes commands only to be used with MiFare Classic (1K or 4K) chips.

Command	Name	Description
AUT	Authentication	Authenticates a sector by giving one absolute block
GAB	Get Access Bits	Return the access bits from a selected block, or sector
STM	Sector Trailer Manipulation	Set new access bits and/or keys
VAL	Value Block Operations	Interface to the MiFare value operations, like initialization, increment, decrement, restore

*Table **7**: Overview of MiFare specific commands*

5.1. Authentication (AUT)

In order to read or write data from or to MiFare classic chips, the respective memory block has to be previously authenticated with a key. The key can either be selected by using the SKU command (set key to use) or can be directly given as a parameter when using the direct (DRT) parameter (direct mode).

The MiFare card has to be selected before this command works. If the Direct Mode is not used, the SKU command has to be performed in any case.

The AUT command authenticates all the blocks in the sector you chose with Block No., i.e. authenticating Block 5 will authenticate Blocks 4 to 7 (the entire sector 1).

NOTE

The *standard password* for MiFare transponders is FF FF FF FF FF FF (six bytes).

Instruction:

```
AUT<SPACE>DRT<SPACE>[Key]<SPACE>{Type}<SPACE>[Block No.]<CR>
```

Command	Description
DRT	Parameter to mark the direct mode and the next parameter is the key
Key	The key to use, 6 Byte ASCII string (12 chars)
Type	Authenticate with key A or B (see …)
Block No.	Block which will be authenticate

Table 8: Overview of parameters of the AUT command

Response, if successful:

```
OK!<CR>
```

Examples:

Direct authentication of block 8 (sector 2) with keytype B and key FFFFFFFFFFFFh

```
AUT<SPACE>DRT<SPACE>FFFFFFFFFFFF<SPACE>B<SPACE>8<CR>
```

Possible error codes:

`UPA<CR>`	Unknown parameter
`BIH<CR>`	Block no. is too high (i.e. bigger than 63 at MiFare 1k)
`ATE<CR>`	Authentication Error (i.e. wrong key)
`NKS<CR>`	No Key Select, select a temporary or a static key (use STK or SSK)
`CNS<CR>`	Card is Not Selected

5.2. Get Access Bit (GAB)

This function returns the access bits from MiFare 1K and 4K cards. The function is able to return the access bits from one block, or all blocks from an authenticated sector. The access bits must be readable for this command.

If Mifare 4K is used and the authenticated block no. is higher than 127, the first three lines represent the first 15 Blocks (each line 5 blocks) and the fourth line the trailer.

Instruction:

```
GAB<SPACE>[Block Nr]<CR>
```

Response, if successful:

State of C1, C2 and C3

```
C1<SPACE>C2<SPACE>C3<CR>
```

Examples:

Block 5 is authenticated and only the access bits from block 5 are required

```
GAB<SPACE>5<CR>
```

Response:

`0 0 1<CR>`	(this equals block mode 4, the standard mode)

Block 13 (sector 3) is authenticated and all blocks of this sector should be returned

```
GAB<SPACE>ALL<CR>
```

Response:

`0 1 0<CR>`	(Block 12 in Block Mode 2)
`0 0 1<CR>`	(Block 13 in Block Mode 4)
`0 1 1<CR>`	(Block 14 in Block Mode 5)
`1 1 0<CR>`	(Block 15 in Access-Mode 3)

Block 145 (sector 33) is authenticated and all blocks of this sector should be read

```
GAB<SPACE>ALL<CR>
```

Response:

`0 1 0<CR>`	(Block 144-148 in Block Mode 2)
`0 0 1<CR>`	(Block 149-153 in Block Mode 4)
`0 1 1<CR>`	(Block 154-159 in Block Mode 5)
`1 1 0<CR>`	(Block 160 in Access-Mode 3)

Possible error codes:

`UPA<CR>`	Unknown parameter
`NMA<CR>`	No MiFare 1k or 4k chip authenticated
`BAE<CR>`	An unauthenticated block is chosen
`BNA<CR>`	Block not authenticated, Block No. is not in authenticated sector
`TNR<CR>`	Tag not responding (Tag is no longer in read range)
`EDX<CR>`	A decimal parameter cannot be interpreted as a decimal value

5.3. Sector Trailer Manipulation (STM)

This function simplifies the usage of the MiFare classic access conditions and key writing. With this command you can change the access bits and don't have to write to the trailer blocks directly which should reduce errors resulting in destroyed transponders. As described in the Appendix, the sector trailer contains information about keys, block-mode and Access-Modes. Use this command to set these access bits and/or keys.

There are different ways to manipulate data in the sector trailer by using these modes:

- Set key and Access Bits (SKA)
- Set Keys Only (SKO)
- Direct over write-data command (only advanced user! Included for upward compatibility to new MiFare Standards, e.g. MiFare+)

5.3.1. Set key and Access bits (SKA)

Use this mode to set both the access keys and the access bits of a specific sector. To change this information, both the access bits and keys have to be writable and the sector authenticated with the correct key. The access bits will be automatically written to the correct bits of the trailer of the given block no.

The meaning of the access bits given by the parameters C1, C2 and C3 depend on the given block no. parameter.:

- If the block no. is a sector trailer block the access bits C1, C2, C3 are interpreted as bits for access mode.
- If the block no. is not the sector trailer but a data block the access bits C1, C2, C3 are interpreted as bits for block mode.

After using this command a re-authentication will be necessary

Instruction:

```
STM<SPACE>SKA<SPACE>[Block No]<SPACE>[C1]<SPACE>[C2]<SPACE>
[C3]<SPACE>[KeyA]<SPACE>[KeyB]<CR>
```

Parameter	Description
Block No.	The data block to modify, in decimal notation
C1, C2, C3	BCD-Coded Mode, 0 or 1
KeyA	MiFare authentication key A; 6 Bytes hexadecimal coded ASCII-string (16 chars)
KeyB	MiFare authentication key B; 6 Bytes hexadecimal coded ASCII-string (16 chars)

Table 9: SKA mode parameter description

Response, if successful:

```
OK!<CR>
```

Examples:

Write Key A (665544332211), Key B (112233445566) and block mode 3 (1 1 0) for block 2

```
STM<SPACE>SKA<SPACE>2<SPACE>1<SPACE>1<SPACE>0<SPACE>6655443322
<SPACE>

112233445566<CR>
```

Write Key A (000000000000), Key B (FFFFFFFFFFFF) and access mode 3 (1 0 1) for block 3

```
STM<SPACE>SKA<SPACE>2<SPACE>1<SPACE>0<SPACE>1<SPACE>0000000000
00<SPACE>

FFFFFFFFFFFF <CR>
```

Possible error codes:

UPA<CR>	Unknown parameter
BAE<CR>	An unauthenticated block is chosen
BNA<CR>	Block not authenticated, Block No. is not in authenticated sector
BNC<CR>	Parameter C1, C2 or C3 missing
AKW<CR>	Access bits or Keys not Writable
UKB<CR>	Use Key B for authentication (in Access-Mode 5 and 6)
UKA<CR>	Use Key B for authentication (in Access-Mode 0 and 4)
TNR<CR>	Tag not responding (Tag is no longer in read range)
NMA<CR>	No MiFare 1k or 4k chip authenticated

5.3.2. Set Key Only (SKO)

Use this command to change only the key of a specific sector. The sector trailer has to be in Access-Mode 6, 1 (authenticated with key B) or 4, 0 (authenticated with key A) for this command to work.

Instruction:

```
STM<SPACE>SKO<SPACE>[Block No.]<SPACE>[KeyA]<SPACE>[KeyB]<CR>
```

Parameter	Description
Block No.	The data block to modify, in decimal notation

C1, C2, C3	BCD-Coded Mode, 0 or 1
KeyA	MiFare authentication key A; 6 Bytes hexadecimal coded ASCII-string (16 chars)
KeyB	MiFare authentication key B; 6 Bytes hexadecimal coded ASCII-string (16 chars)

Table 10: SKO mode parameter description

Response, if successful:

```
OK!<CR>
```

Examples:

Sector 5 which contains block 20 get the keys 112233445566 (key A) and 665544332211 (key B)

```
STM<SPACE>SKO<SPACE>20<SPACE>112233445566<SPACE>665544332211<CR>
```

Possible error codes:

UPA<CR>	Unknown parameter
BAE<CR>	An unauthenticated block is chosen
KNC<CR>	Keys not changeable
UKA<CR>	Use Key A for authentication
UKB<CR>	Use Key B for authentication
BNR<CR>	Block not readable, i.e. wrong key, see Block –and Access Mode
BNA<CR>	Block not authenticated, Block No. is not in authenticated sector
NMA<CR>	No MiFare 1k or 4k chip authenticated

5.4. Value block Operation (VAL)

This command is used to use the integrated MiFare valueblock operations. A value block is able to save a signed 4 byte value and one address byte (i.e. own block address). The value is saved LSB first, i.e. 00000035h written as parameter looks like 35000000h. The value can be manipulated by four different ways (always depending on access bits). It is usually used to store information on credit values for e-payment or e-ticketing situations.

There are five different modes for this command:

- Initialization – the first step to use the next operations (sets a initial value/address)

- Increment - adds a value (given as parameter) to the value present in a chosen block (inputblock) and writes the result to the outputblock. (Mode 3)
- Decrement - subtracts a value (given as parameter) to the value present in a chosen block (inputblock) and writes the result to the outputblock. (Mode 3, 4)
- Direct Write - writes 4 value bytes and one address byte direct to the Block (Mode 3)
- Restore - Writes the Date from the outputblock to the inputblock. (Mode 3, 4)

5.4.1. Initialization of a value block (INIT)

In order to use the Increment, Decrement and Restore function, the data block has to be configured as a value block (Block Mode 3) or in transport configuration (Block Mode 0). This function initializes the MiFare data block to the correct format. In this way an initial value and an initial address has to be given (see Backup Configuration in chapter … for details of the address). If the initialization is done, the block mode can changed to 4 via the STM command. The block has to be writeable, in block mode 0 or 3. When authenticated with key B and key B is readable, the block is not read/writable.

Instruction:

```
VAL<SPACE>INIT<SPACE>[Value]<SPACE>[Block
No.]<SPACE>[Address]<CR>
```

Parameter	Description
Value	Signed and always positive 4 byte, hexadecimal Value
Block No.	The data block to modify, in decimal, i.e. for MiFare 1k 0..63, for MiFare 4k 0..255
Address	Initial address, one decimal byte

Table 11: Init mode parameter description

Response, if successful:

```
OK!<CR>
```

Examples:

The Block Mode is set to mode 3 by another way. The initial value should be 2000h. The block to configure is block number. 4.

```
VAL<SPACE>INIT<SPACE>00002000<SPACE>04<CR>
```

The Access bits are changeable and the block number 5 should become a value block with write and increment rights. The initial value should be 2020h.

```
VAL<SPACE>INIT<SPACE>SAB<SPACE>WI<SPACE>00002020<SPACE>05<CR>
```

Now the block becomes Mode 4. The value is only a dummy.

```
VAL<SPACE>INIT<SPACE>SAB<SPACE>00202000<SPACE>05<CR>
```

Possible error codes:

`UPA<CR>`	Unknown Parameter
`NMA<CR>`	No MiFare 1k or 4k chip authenticated
`WDL<CR>`	Initial value is not 6 bytes long
`EDX<CR>`	In/Output block or value missing, or other character than '0' to '9'
`EHX<CR>`	The initial value is missing, or other characters the 0.. 9 and A .. F
`KBR<CR>`	Key B is readable
`BNW<CR>`	Block-Not-Writable: authenticated with key A, but not in block mode 0
`BME<CR>`	Block Mode Error, not 0 or 3 (not writeable with value block function)
`NDB<CR>`	the chosen Block is no Data Block, it's a trailer
`BAE<CR>`	Block access error, i.e. wrong key, see Block –and Access Mode
`BNA<CR>`	Block not authenticated, Block No. is not in authenticated sector
`TNR<CR>`	Tag not responding

5.4.2. Increment (INC) and Decrement (Dec)

As described at begin of this chapter, this function adds or decrements a value to a value present in the inputblock. Finally the result of this operation will be saved in the outputblock.

Conditions:

- Data block has to be configured to Block Mode 0 or 3 for increment
- Data block has to be configured to Block Mode 0, 3 or 4 for decrement
- Outputblock and inputblock have to be in the same sector

If input/output blocks are different blocks, use the restore command, else the increment/decrement function works only one time (the results are always the same)

Instruction:

```
VAL<SPACE>{MODE}<SPACE>[Value]<SPACE>[Inputblock]
<SPACE>[Outputblock]<CR>
```

Parameter	Description
MOD	Selected either increment (INC) or decrement (DEC)
VALUE	unsigned hexadecimal value (summand/subtrahend)
Inputblock	1 decimal Byte, i.e. 0 to 63 for Mifare 1k, or 0 to 255 for Mifare 4k, but not trailer
Outputblock	1 decimal Byte, i.e. 0 to 63 for Mifare 1k, or 0 to 255 for Mifare 4k, but not trailer

Table 12: INC and DEC mode parameter description

Response, if successful:

```
[VALUE]<CR>          4 bytes long result of the operation
```

Examples:

Increment the value from block 32d by 10d and write the result to block 32d

```
VAL<SPACE>INC<SPACE>10<SPACE>32<SPACE>32<CR>
```

Decrement the value from block 32d by 10d and write the result to block 32d

```
VAL<SPACE>DEC<SPACE>10<SPACE>32<SPACE>32<CR>
```

Increment the value from block 32d by 20d and write the result to block 33d

```
VAL<SPACE>INC<SPACE>20<SPACE>32<SPACE>33<CR>
```

Possible error codes:

UPA<CR>	Unknown Parameter
TNR<CR>	Tag no response, i.e. value block not incrementable
EDX<CR>	In/Output block or value missing, or other character than '0' to '9'
NDB<CR>	The chosen block is no data block but a trailer
NMA<CR>	No MiFare 1k or 4k chip authenticated
ONE<CR>	Operation not Executed, Result smaller/bigger than ±2,147,483,647
VNI<CR>	The Value block is not in the right format, use INIT comman

5.4.3. Restore

This command is used for powerful backups. If the input –and outputblock are not the same, this command restores the result written in the outputblock to the inputblock. The outputblock has to be in the correct value block format for this command to work.

Instruction:

```
VAL<SPACE>REST<SPACE>[ Outputblock] <SPACE>[ Inputblock]<CR>
```

Response, if successful:

```
OK!<CR>
```

Examples:

The result of an operation is saved in block 29d and should restore to 28d

```
VAL<SPACE>REST<SPACE>29<SPACE>28
```

Possible error codes:

`UPA<CR>`	Unknown Parameter
`TNR<CR>`	Tag no response, i.e. value block not incrementable
`EDX<CR>`	In/Output block or value missing, or other character than '0' to '9'
`NDB<CR>`	The chosen block is no data block but a trailer
`NMA<CR>`	No MiFare 1k or 4k chip authenticated
`BNA<CR>`	In- or Outputblock is not authenticated
`VNI<CR>`	The Value block is not in the right format, use INIT command first

6. Appendix

Appendix 1: CRC Calculation

```
// this function calculates a CRC16 over a unsigned char Array with, LSB first
// @Param1 (DataBuf): An Array, which contains the Data for Calculation
// @Param2 (SizeOfDataBuf): length of the Data Buffer (DataBuf)
// @Param3 (Polynom): Value of the Generatorpolynom, 0x8408 is recommended
// @Param4 (Initial_Value):  load value for CRC16, 0xFFFF is recommended for
//                           host to reader communication
// return: calculated CRC16

unsigned short GetCrc(              unsigned char *DataBuf,
                                    unsigned char SizeOfDataBuf,
                                    unsigned short Polynom,
                                    unsigned short Initial_Value)
{
        unsigned short Crc16;
        unsigned char Byte_Counter, Bit_Counter;

        Crc16 = Initial_Value;
        for (Byte_Counter=0; Byte_Counter < SizeOfDataBuf; Byte_Counter++)
        {
                Crc16^=DataBuf[Byte_Counter];
                for (Bit_Counter=0; Bit_Counter<8; j++)
                {
                        if (( Crc16 & 0x0001)==0) Crc16>>=1;
                        else Crc16=(Crc16>>1)^Polynom;
                }
        }
         return (Crc16);
}
```

Appendix 2: Error Codes:

Error Code	Description
EDX	Error Decimal value Expected, or is missing
EHX	Error Hexadecimal value Expected, or is missing
IOS	Input and Outputblock are not in the same Sector
TNR	Tag Not Responding
UPA	Unknown Parameter
NMA	No MiFare classic chip Authenticated
WDL	Wrong Data Length of hex-string-parameter
NDB	No Data Block
KBR	Key B is Readable
ONE	Operation Not Executed
BME	Block Mode Error, not 0 or 3 (not writeable with value block function)

BNW	Block Not Writable
BAE	Block Access Error
BNA	Block Not Authenticated
AKW	Access bits or Keys not Writable
UKB	Use Key B for authentication
UKA	Use Key B for authentication
KNC	Keys not changeable
BIH	Block is too high (i.e. bigger than 63 at MiFare 1k)
ATE	Authentication Error (i.e. wrong key)
NKS	No Key Select, select a temporary or a static key
CNS	Card is Not Selected
NB0	Number of Blocks to Read is 0

Table 13: Overview of error codes

Appendix 3: General Information on MiFare Systems

Since MiFare transponders have serveral specialties esp. with regard to the access system used, this paragraph is meant to give a quick overview about these topics. For an even deeper understanding of the matter, please refer to the respective datasheets of the MiFare transponders you are using. You can get these directly from NXP after signing an NDA via their website.

Memory Organisation

The memory of MiFare classic chips is organized in sectors composed of several numbers of data blocks and one trailer. MiFare 1K chips contain 16 sectors of 3 data blocks and one (the fourth) trailer (Table 14). For the lower 32 sector of MiFare 4K chips the same applies. The higher 8 sectors are composed of 15 data blocks and one (the 16th) trailer block(Table 15). All blocks are read-/writable only if the corresponding sector was successfully authenticated.

The Trailer Block:

The trailer contains two secret keys (A and B) to authenticate the corresponding sector and information about access rights (the access bits). Teh trailer block is always the last block in a sector. This means that each sector can have its own keys for giving write or read access.

Data blocks:

The data blocks contain 16 read-/writable bytes depending on the access bits in the sector trailer, except block 0 in sector 0, which is a read-only manufacturer block. These blocks can configured as normal read/write blocks or as value blocks.

Sector	Block	Absolute Block Nr	Funktion
15	3	63	Sector Trailer (Key A, access bits, Key B)
15	2	62	Data
15	1	61	Data
15	0	60	Data
…	…	…	…
0	3	3	Sector Trailer (Key A, access bits, Key B)
0	2	2	Data
0	1	1	Data
0	0	0	Data

Table 14: Memory organization of the MiFare 1k chip (16 sectors á 4 blocks á 16 bytes (Sector 0 in Block 0 is the manufacturer block)

Sector	Block	Funktion
32 to 39	15	Sector Trailer (Key A, Access, Key B)
32 to 39	14	Data
32 to 39	…	…
32 to 39	0	Data
Lower blocks		
0 to 31	3	Sector Trailer (Key A, Access, Key B)
0 to 31	2	Data
0 to 31	1	Data
0 to 31	0	Data

Table 15: Memory organization of the MiFare 4k chip (Sector 0 to 31: 4 blocks á 16 bytes (Sector 0 in Block 0 is the manufacture block); Sector 31 to 39: 16 blocks á 16 bytes)

At authentication and all read/write processes the zero base absolute block number must given. This is calculated with following equation:

for MiFare 1k or 4k and absolute block Nr < 128: Block Nr = Sector*4 + Block in Sector

for MiFare 4k and absolute block Nr > 128: Block Nr = Sector*16 + 128 + Block in Sector

where Block No. is the absolute zero based block number (0..63 for MiFare 1k, or 0..255 for MiFare 4k) and Block in Sector is the position of the block in the sector (0..3 for MiFare 1k & 4k (<128) , or 0..15 MiFare 4k (>128))

Access Rights

All MiFare Cards have a fine grained access rights system. Each sector can be secured using two different keys (Key A and Key B). Using access bits, you can give read or write access to

one or both of the keys for each block. That means, that e.g. you can use Key A in your customer application which is only able to read the data, but use Key B in your internal application to initialize the cards with full write access.

To identify the access rights for a sector there are three bits, called access bits C1, C2 and C3. With these three bits eight different modes are possible with these access bits. C1 is the LSB.

Example:

C1 C2 C3 Mode

1 1 0 3

There are four access rights per sector (one for each three data blocks and one trailer block), so each block at MiFare 1k and the lower 32 blocks at MiFare 4k has its own three access bits. At the higher 8 sectors of MiFare 4k five blocks shares one mode.

So depending on wether you set the access bits of a data block or of a trailer block (the fourth block of each sector) these bits change their meaning.

When writing the access bits of a data block you can define the following things for this block (this setting is called „block mode“).

- Is the data block readable/writeable and by which key (Key A or Key B or both)
- Is it a value block or a read/write block
- Is the block locked (not read/writable)

Access Conditions				Application	Access bits	Block Mode
Read	*Write*	*Increment*	*Decrement, Restore*		*C1 C2 C3*	
A|B	A|B[1]	A|B[1]	A|B[1]	transport configuration	0 0 0	0
A|B	NEV	NEV	NEV	Read/write Block	0 1 0	2
A|B	B[1]	NEV	NEV	Read/write Block	1 0 0	1
A|B	B[1]	B[1]	A|B[1]	Value Block	1 1 0	3
A|B	NEV	NEV	A|B[1]	Value Block	0 0 1	4
B	B[1]	NEV	NEV	Read/write Block	0 1 1	6
B	NEV	NEV	NEV	Read/write Block	1 0 1	5
NEV	NEV	NEV	NEV	Read/write Block	1 1 1	7

Table 16: Access Bit meaning in „Block-mode“

Block Mode 0: This is the transport configuration (delivery state). In this mode the block is readable and all data manipulating commands are enabled.

But who is allowed to change the Block Mode itself? The sector trailer has its own access bits, where exactly this and some other details are configured. The set of access right stored in the trailer block is called „Access Mode". Here you can configure whether Key A, Key B or the access bits are read/writeable.

Access condition for						Access bits			Access-Mode
Access Bits		Key A		Key B					
read	write	read	write	read	write	C1	C2	C3	
A	NEV	NEV	A	A	A	0	0	0	0
A|B	NEV	NEV	B	NEV	B	1	0	0	1
A	NEV	NEV	NEV	A	NEV	0	1	0	2
A|B	NEV	NEV	NEV	NEV	NEV	1	1	0	3
A	A	NEV	A	A	A	0	0	1	4
A|B	B	NEV	NEV	NEV	NEV	1	0	1	5
A|B	B	NEV	B	NEV	B	0	1	1	6
A|B	NEV	NEV	NEV	NEV	NEV	1	1	1	7

Table 17: Access-Modes (NEV = Never)

Example:

Access-Mode 4: This is the transport configuration (delivery state). In this mode the access bits can only be read or written when using key A for authentication. The same applies to Key B. Key A can only be written.

Appendix 5: Overview of Tag Properties

Tag-type	SAK (Level 1/Level 2)	ATQA	UID Length
Mifare 1k	08h/ XX	0400h	4 Bytes
Mifare 4k	18h/ XX	0200h	4 Bytes
Mifare Desfire	24h/20h	4403h	7 Bytes
Mifare Ultralight	04h/00h	4400h	7 Bytes

Table 18: Different characteristics of MiFare Chips

7. Version Control

Version	*Change*	*by*	*Date*
1.0	created	KD	11.3.2009

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